

Leaf & Yard Waste



Composting Manual

Alberta
ENVIRONMENT

 **OLDS
COLLEGE**

Leaf and Yard Waste Composting Manual

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1. Introduction

This manual was developed for Alberta Environment, Action on Waste to help municipalities, Regional Districts, institutions and organizations in Alberta implement leaf and yard waste composting. This manual includes a step-by-step guide for materials handling, feedstock preparation, monitoring and composting using aerated windrows. The manual is intended to identify some of the factors that affect the success of long-term programs as well as provide technical information for managing **leaf and yard waste** composting.

Yard Waste – leaves, grass clippings, yard trimmings and other organic debris.

This manual provides information that may be useful to a wide range of municipal groups and organizations considering leaf and yard waste composting, including:

- municipal districts
- regional districts
- golf course operators
- hospitals
- educational facilities
- large institutional facilities
- cities and towns

2. Why Compost?

Composting is an alternative to landfilling and can be part of every community's waste management program.

Baseline landfill volume data used by the Canadian Council of Ministers of the Environment (CCME) in 1989 estimated Canada's landfill volumes to exceed 21.2 million tonnes per year, not including agricultural and agri-food wastes, pulp and paper and commercial forestry by-products, and most biosolids from sewage treatment. These wastes are typically disposed of by landfilling, landfarming or incineration.

In Alberta compostable material comprises up to 70% of the waste generated by most communities (Alberta Environmental Protection: 1994). This figure includes household organic wastes, leaf and yard waste, all paper and cardboard, and sewage just to name a few of the organic waste streams.

In areas that have long growing seasons and leafy trees, there is a large amount of organic material generated each year that is commonly sent to the landfill. This material has value in nutrient and organic matter cycling (as a soil amendment) and could be utilized through composting. Not only can these valuable nutrients be harnessed; disposal issues associated with landfilling organic material area also avoided.

Leaf and Yard wastes are set apart from organic materials because they naturally break down into a humus-like material. However, when placed in a landfill organic materials decompose under anaerobic conditions. One of the by-products of anaerobic decomposition is methane, an odorous gas that contributes to the greenhouse effect. Rain and groundwater percolation through the landfill and combined with decaying organic matter produce weak acids. As these acids are washed through the landfill, groundwater protection may be affected.

Reducing organic material in landfill can help reduce the adverse effects and costs associated with methane and leachate production.

Other benefits include:

- ability to compost paper and cardboard materials that cannot reach centralized services
- responsibility and accountability for dealing with waste in the community
- composting is a **decentralized** system. Composting programs can be set up in the community producing the waste rather than paying for expensive transportation networks to get materials processed and marketed.

Composting organic waste can significantly increase the life of landfills.

3. What is Composting?

Composting is a controlled biological process in which a succession of microbial populations converts organic material into a biologically stable product.

Composting can be used to produce compost, or composting can be implemented specifically as a waste treatment process. The real benefits of composting result when you do both.

Composting requires attention to:

- Carbon and nitrogen ratios
- Moisture content
- Oxygen availability
- Maintenance of favourable temperatures

Composting is typified by a microbially active thermophilic (high temperatures of 45-65°C) period while easily digestible materials are available, followed by a lower temperature curing period as more complex materials are slowly digested.

The extent of composting required for a specific material depends on the desired processing goal. Processing duration is also dependent upon materials handling and the level of process control employed. As in all biological processes, feedstock quality and preparation affects process management and final product quality.

There are two types of biological degradation processes; these are typically referred to as **aerobic** (in the presence of oxygen) and **anaerobic** (absence of oxygen).

aerobic – takes place in the presence of oxygen

The presence of oxygen is important when designing a composting operation, regardless of size.

anaerobic – takes place in the absence of oxygen

Organic material decomposes as micro-organisms break down plant material to obtain the nutrients they need to grow. Some of these micro-organisms can decompose organic material only when oxygen is present. The aerobic organisms are able to decompose much more quickly than the anaerobic micro-organisms. If the pile does not get turned (aerated), gets compacted, or becomes too wet, the oxygen levels go down and the anaerobic organisms take over. The compost pile begins to smell as anaerobic bacteria release methane gas and hydrogen sulfide, a gas that smells like rotten eggs.

4. The Compost Facility

When you start to compost it is important to know **why** you are composting and **what** it is that you want to accomplish. This is an important step for understanding what you will need for designing and implementing composting in your community or organization. More often than not this step is overlooked, resulting in a process which is unable to produce quality compost. **Guidelines for Compost Quality** have been set by the Government of Canada and the Provinces, as have **Code of Practice for Composting Facilities**. These Guidelines and Codes are available from Alberta Environment (see Appendix B).

Site Selection

The location of the composting site should allow easy access, a minimum of travel and materials handling, and a firm surface to support vehicles under varying weather conditions. Often the most convenient site is close to a landfill facility or in a municipality yard. However, the convenience of a particular site must be weighed against factors such as, proximity to residential neighbours, visibility, drainage and run-off control. Sites near sensitive locations, such as schools, hospitals, and nursing homes should be avoided. The composting site should also be distant from neighbouring residences and preferably out of their view. If not, public relations and odour control may be more time-consuming.

Make a sketch of the compost facility showing all key areas. Show the prevailing wind direction, traffic flow patterns, the land slope, run-off patterns, surrounding land uses, and pertinent environmental information such as location of wetlands or water sources.

The type of composting process you choose for your site will determine the amount of available space needed. Specific criteria for site preparation are outlined in the **Code of Practice for Composting Facilities**.

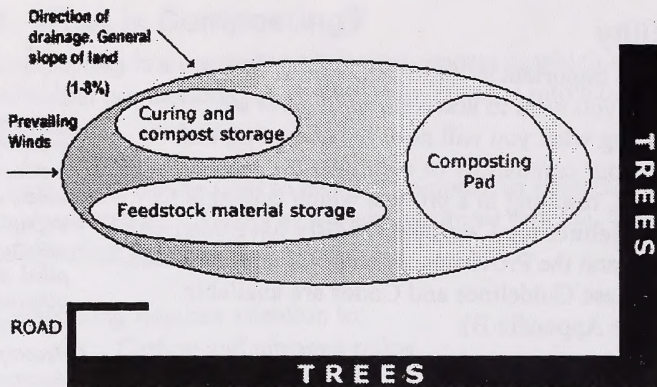
Collecting the Materials

The ability to understand human behaviour plays a key role when designing and implementing collection systems. While there are a number of collection systems available, the role of education, marketing and promotion of composting is paramount. Whether the collection system is curb-side collection, site drop-off, or community site pick-up, it is very important to make the community aware of expectations and the reasons behind the composting project. You will need to identify the quantities and composition of wastes. Often, community forums are successful. Other situations indicate a brief survey works the best for information collection.

compost – compost is a group of organic residues (leaf and yard waste) or a mixture of organic residues and soil that have been piled, moistened, and allowed to undergo aerobic biological decomposition (composting)

humus – humus is a dark or black carbon-rich relatively stable residue resulting from the decomposition of organic matter (composting)

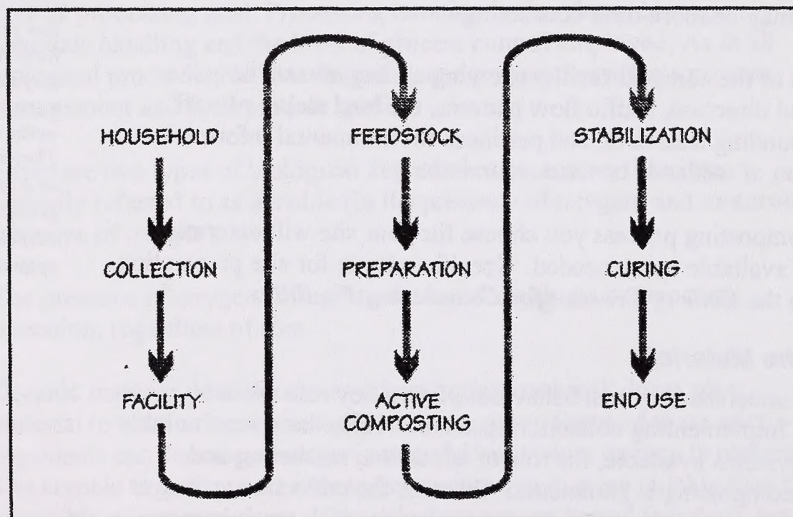
What is a windrow? A windrow is a long, relatively narrow, and low pile. Windrows have a large exposed surface area that encourages passive aeration and drying. They are constructed in a manner that will provide insulating value and heat retention.



Understanding your market and natural human behaviour patterns makes the difference between "good" and "great" programs. As indicated above, community forums will enable you to assess the amount of support you have for a composting program. The willingness to participate will determine the volume of

material that you will receive. You will need to identify that you are only accepting leaf and yard waste material. Be very specific in what you are expecting; leaves, grass clippings, small trimmings of branches only (less than 4cm in diameter), and vegetable and flower garden waste.

The following diagram outlines the flow of materials through the producers, collectors, composters, and end-users.



The Composting Process

5. Process Technologies

Composting leaf and yard waste can be accomplished through a number of different process technologies, including:

Type of Composting	Volume of Waste Able to be Composted
<ul style="list-style-type: none">• static pile composting• aerated windrows• simple channel and tunnel systems• complex channel and in-vessel systems	<ul style="list-style-type: none">• 50 to 1,500 tonnes per year• up to 25,000 tonnes per year• up to 100,000 tonnes per year• up to 250,000 tonnes per year

The various technologies for composting have been widely explored and information is readily available through many sources. Some of the most common technologies for Leaf and Yard Waste Management are passively managed static piles and windrow composting.

Each of these techniques has its own pros and cons and many variations exist and are working well.

This manual will focus on the aerated windrow composting technology, as it has the widest application, particularly in Alberta.

The **Composting Council of Canada** has compiled and reviewed some of these technologies in their *Composting Technologies & Practices* guide. Numerous sites on the internet also offer very good information (see Appendix B).

6. Feedstock Preparation

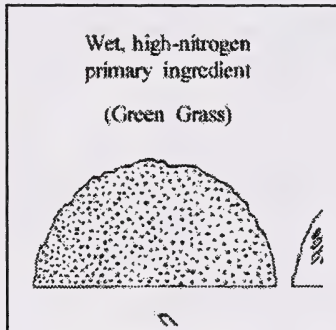
Feedstock preparation is an important step in which the feedstock is prepared before being left to compose. During feedstock preparation, the characteristics of the feedstock may be changed both physically and chemically. The changes made during this stage will optimize the microbes performance during the composting phase.

Depending on the type of collection system you have employed it may be important for you to have an area of your facility available for feedstock preparation.

Feedstock – the material of which a compost pile or windrow is composed of is referred to as the feedstock. Leaf and yard waste for the purpose of this manual is considered the feedstock.

During this phase of your operation you will need to:

- remove contaminants or other non-compostable material
- reduce particle size to increase the total surface area of the feedstock to allow for better aeration.
- add either a carbon or a nitrogen source to obtain a desirable C:N ratio.
- add moisture to the material to raise the moisture content to an acceptable level for microbial life to flourish.
- add a bulking agent to increase the airflow through the material (wood chips or straw).



Combining raw materials to achieve the desired characteristics for composting.

Source: On-Farm Composting Handbook, Page 14.

Removal of Inorganic Contamination: Feedstock Recovery

Feedstock recovery is the physical process of separating compostable materials from non-compostable materials. Ideally, **source separation** ensures that the feedstocks do not mix inorganic waste with the leaf and yard waste. However, reality is that these materials seem to inevitably find their way into the feedstock; they don't compost and must be removed.

Screening

Inorganic contamination must typically be removed from the feedstock using various sizes and dimensions of screens, as it may:

- post danger at the composting facility
- cause equipment breakdowns, and maintenance problems
- can blow around at the facility making it look unsightly
- interfere with the biological process of decomposition
- pollute the finished product

Contaminants typically include:

- | | |
|----------------------|----------------|
| • plastic bags | • oils |
| • plastic containers | • paints |
| • glass | • pesticides |
| • metal | • herbicides |
| • batteries | • treated wood |
| • gasoline | • solvents |

These contaminants may hinder or even stop the biological activity within a compost pile and should be removed from a feedstock upon delivery and disposed of properly.

MEASURING THE AMOUNT OF CONTAMINANTS

This test is to determine the amount of contaminants that that may be present in a compost sample.

To measure the amount of contaminants do the following:

1. Take a sample of compost
2. Weight the sample of compost
3. Screen the compost
4. Visually inspect the material left on the screen
5. Separate the contaminants
6. Weigh the contaminants
7. Calculate the percentage of contaminants by ...

$$\% \text{ of contaminants} = \frac{\text{weight of contaminants (\#6)}}{\text{weight of sample}} \times 100$$

8. Record the percentage. If the % contaminants is greater than 30, then additional education needs to be addressed.

Ensure that nails and other inorganic materials do not contaminate the windrows during the preparation stage. Large wooden pieces that may bypass the shredder should be carefully removed.

Testing, Recording and Reporting Procedures

Testing, recording and reporting procedures are very important management tools. These procedures must be established as part of the composting process. The following is a schedule of the types of tests that need to be conducted during feedstock preparation, composting, stabilization and curing phases. An initial analytical test of compost nutrients as follows: Moisture, TN, P, K, S, Ca, Mg, Na, Zn, B, Mn, Cu, Fe, Mo, Al, TC, pH, E.C., Ash, OM, SAR, C/N. This testing is not as important if your feedstock is strictly limited to leaf and yard waste. However, if you find your contamination rate is high you should send your samples off for analysis (as per attached).

	C/N Ratio	Volume & Weight	pH	Temperature		Oxygen Content	Particle Size	Odour	Bulk Density	% Moisture
				Ambient	Core					
Individual Feedstocks	X	X	X				X		X	X
Combined Feedstocks	X	X	X				X		X	X
Daily Measurements				X	X					
Weekly Measurements			X			X		X	X	X
Monthly Measurements		X								
Final Measurements	X	X			X		X			

These tests will be discussed in greater detail as they relate to each stage.

Equipment Required for Monitoring

- Oxygen probe (suggested)
- Long stem temperature probe
- Ziploc bags
- Shovel
- Monitoring sticks (stakes marking monitoring zones)
- Standard recording forms (samples page 14/15)
- Screens of various sizes (1/2", 1", 1.5", 2", 3")
- Stirring sticks

Initial and Final Measurements

PARAMETERS	DATE	START	DATE	FINISH
Chemical				
C/N Ratio				
pH				
EC				
N				
P				
K				
Heavy Metals				
Analysis				
Physical				
% Moisture				
Bulk Density				
Particle Size				
Temperature				
Ambient Temp				
Volume				
Biological				
Cress				
Growout				

Bulk Density Data Sheet

Project #:			Project Name:			
Start Date:			End Date:			
Date	Sample	Wet Wt (kg)	Moisture (%)	Dry wt. (kg)	Volume (L)	Bulk Density (kg/m ³)
Example	Pulp sludge	12.8	63.8	4.634	20	231.68
Example	Soil	50	63.8	18.100	20	905.00
Example	Soil	50	75	12.500	16	781.25
				0.000		#DIV/0
				0.000		#DIV/0
				0.000		#DIV/0
				0.000		#DIV/0
				0.000		#DIV/0
				0.000		#DIV/0
				0.000		#DIV/0
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				0.000		#DIV/0
				0.000		#DIV/0
				0.000		#DIV/0
				0.000		#DIV/0
				0.000		#DIV/0

Daily Measurements

Project Name: _____							
Project Code: _____							
TEMPERATURE							
Date	Day	Ambient	Rep 1	Rep 2	Rep 3	Rep 4	Average
	0						
	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						
	11						
	12						
	13						
	14						
	15						
	16						
	17						
	18						
	19						
	20						
	21						
	22						
	23						
	24						

Sampling

Sampling is the process of obtaining representative samples of feedstock and windrow material. The number, size, type and frequency of sample is dictated by the test being conducted.

Incoming volumes of feedstocks should be monitored in accordance with the *Code of Practice for Composting Facilities*. As well, records of outgoing volumes should be recorded, again in accordance with the *Code of Practice*.

The diagram illustrates a cross-section of a windrow. A circular core is shown with a radius of 40 cm. Two sampling points are marked with asterisks (*) at a distance of 25 m from the center. An arrow points from the windrow to a 'Ziplock Bag' form.

Ziplock Bag

DATE _____		INITIALS OF SAMPLER _____	
SOURCE _____			
TIME _____		SAMPLE PRESERVATION TECHNIQUE _____	
SAMPLE # _____			

Analytical Services

A good analytical laboratory can be used to help identify the composting parameters outlined in the section entitled "What is Composting?" as well as help maintain that the compost is suitable for use.

Analytical results should be obtained for the following after the compost recipe is formulated and combined: available N, available C, organic matter, TN, P, Ca, Mg, Na, available organic matter, C/N, TC, E.C., pH, moisture, ash, SAR, available C/N.

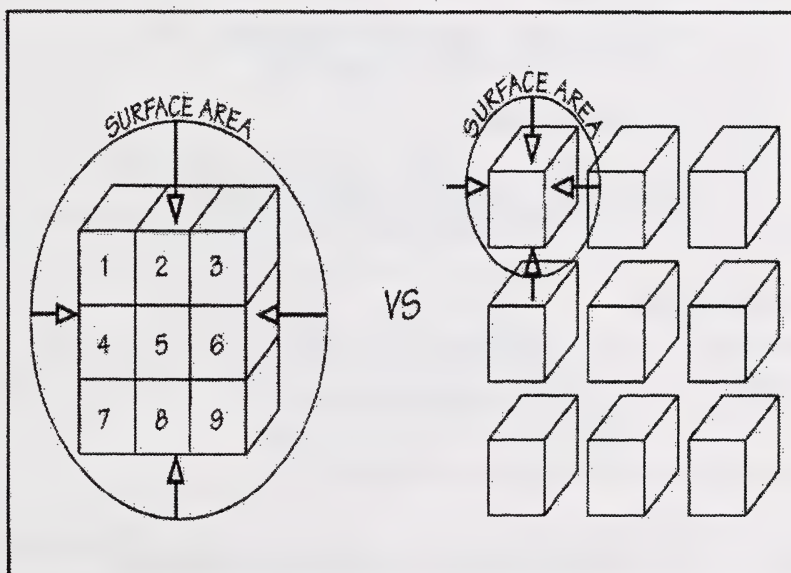
When you have mature compost you should have a CCME metals scan completed.

Particle Size

Particles of smaller size allow for enhanced microbial activity and will decompose at a higher rate. Microbial activity occurs on the surface of the particles and the surface area of a large particle is only a fraction of its total volume. However, in order to keep compression of the compost to a minimum (thereby reducing available oxygen) particle size cannot be too small. This calls for the use of judgement on the part of the workers handling the material.

The target particle size should be from 25mm to 50 mm (1 to 2 inches). Particles of this size will undergo vigorous microbial activity as well as expose them to optimal oxygen and moisture. Appropriate particle size can be achieved by using mechanical means to reduce the material to a more acceptable size.

A shredder or grinder can be utilized to reduce particle size. Shredders and grinders are usually made up of a rotating drum with several teeth welded to it and a grating that the teeth pass through as the drum turns. Material that is too large to pass through the grating is broken up by the teeth as they rotate. By adjusting the openings on the grating, particle size can be controlled.



Measuring the Particle Size

MEASURING PARTICLE SIZE

Testing particle size is important for determining the maturity of compost. As compost matures particle size decreases. This test separates particles based upon size.

To measure particle size, do the following:

1. Select a sample of compost
2. Weigh the sample
3. Pass the sample over a set of screens placed in descending order according to size
4. Weigh the material that is left on each screen after screening
5. Calculate the percentage of the original weight by...

% of each particle size =

$$\frac{\text{weight of material remaining on each screen (\#4)}}{\text{original weight of sample (\#2)}} \times 100$$

6. Record the percentage

Finished compost should have particle sizes ranging from .25" to .75", depending on the intended end use.

Amending the Mix

In order to ensure rapid decomposition of the compost material it may be necessary to add an amendment or a number of amendments. Amendments can include a great number of materials ranging from water to fertilizer.

Addition of amendments is necessary to ensure:

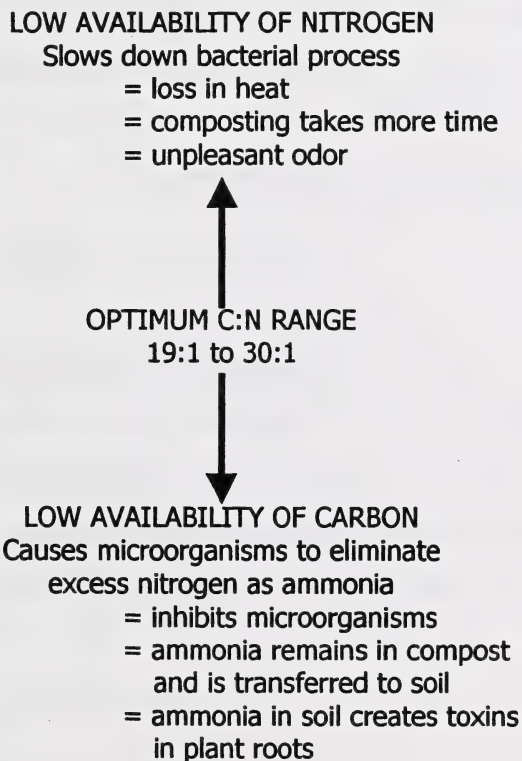
- Proper C:N ratio, 30C:1N
- Bring up the moisture levels, using water or recovered leachate
- Adjust void spaces in your compost, to ensure oxygen availability

The addition of any amendments should always occur prior to turning and mixing the compost. Testing of parameters such as moisture should occur prior to the turning stage. Amendments should be added to the composting mass and the compost should be turned shortly afterwards. This turning will minimize the loss of the additives to the environment.

Adjusting the C:N Ratio

The C:N ratio is the proportion of the mass of carbon to the mass of nitrogen. Carbon is measured as the mass of carbon in the unfixed form (biodegradable). Nitrogen is measured as the total amount of organic nitrogen. A C:N ratio of 30:1 for the initial feedstock is desirable. This may be achieved by blending materials such as dry leaves which possess a high C:N ratio (200:1 or greater), with materials such as fresh grass clippings which have a lower C:N ratio (12:1).

Storing and seasonal management of feedstock – leaf and yard waste are an excellent mix of carbon and nitrogen materials. Unfortunately these materials are not always produced at the same time. As a result, it may be necessary to store a feedstock (leaf waste) from one season for the next. Storing leaves ensures that a carbon feedstock is available for the next growing season.



A short cut formula for two ingredients (for example, leaves plus grass clippings):

$$a = \frac{\%N_b}{\%N_a} \times \frac{(R-R_b)}{(R_a-R)} \times \frac{(1-M_b)}{(1-M_a)}$$

a = kg of ingredient a (ingredient 1) per kg of ingredient b (ingredient 2)%
 R = desired C:N ration of the mix N = % of Nitrogen
 Ma = moisture content of ingredient A Ra = C:N ratio of ingredient A
 Mb = moisture content of ingredient B Rb = C:N ratio of ingredient B

Adjusting Moisture

An optimum moisture content of 50% to 60% should be maintained. Moisture content must be controlled to establish a proper environment for microbial life. Moisture should be measured prior to turning and mixing, then add water if required.

A moisture content below 40% may cause the composting process to come to a complete stop. A moisture content of more than 60% can be detrimental to the microbes, as it will prevent oxygen from permeating through to the microbes.

To adjust moisture content:

1. Add either water or recovered leachate to increase the moisture content of the compost.
2. Add dry material such as dry leaves, sawdust, straw, or wood chips to decrease to moisture content of the compost.

MEASURING MOISTURE

Moisture content is measured by:



1. Obtain a sample of feedstock
2. Weigh the sample
3. Record the weight
4. Dry the sample in a "drying oven" (microwave will do)

1/2 cup (10 gram) sample should take about 3 - 4 minutes in microwave

5. Weigh the dried sample
6. Calculate the percentage of moisture by...

$$\% \text{ moisture} = \frac{\text{original weight (\#3)} - \text{dry weight (\#5)}}{\text{original weight (\#3)}} \times 100$$

7. Record the percentage of moisture

Simple Moisture Testing

If you take a handful of compost:

- squeeze it and it crumbles it is too dry
- squeeze it and it is like a sponge it is the desired moisture content
- squeeze it and water comes out it is too wet.

Adjusting Oxygen Availability

Grass clippings and soft wet green material tend to mat and eliminate air space. Adding straw or small twigs can prevent this from happening.

Aeration is closely linked to moisture content. Oxygen transfer occurs in the spaces between the particles of material being composted. These spaces or voids can contain either water or air; the more water in the voids, the less air. The space that remains available for oxygen is called available air space.

*available air space –
the space which
remains available for
oxygen.*

Bulking agents (materials with structure - straw/wood chips) are added when the ability of the feedstock to maintain these air spaces is not available.

The amount of bulking agent to be added, will depend upon moisture level, oxygen level, C/N ratio, and temperature.

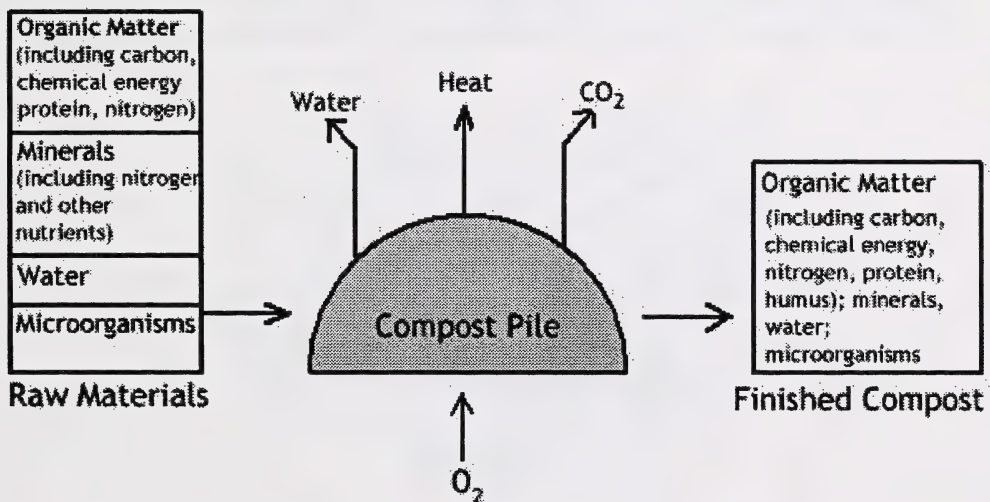
How to measure oxygen content is discussed on page (26).

7. Composting

When the feedstock is prepared, it can be placed into windrows (or vessels, or piles) to be monitored.

The composting process includes such parameters as:

- Managing the oxygen content to ensure adequate microbial activity.
- Controlling temperature, to maintain maximum decomposition rates, and to ensure that pathogenic species are kept to a minimum.
- Addition of water to maintain proper moisture levels for microbial activity.
- Turning to ensure a homogenous moisture content and to aerate the windrow.



The Composting Process. The carbon, chemical energy, protein, and water in the finished compost is less than that in the raw materials. The finished compost has more humus. The volume of the finished compost is 50% or less of the volume of raw material.

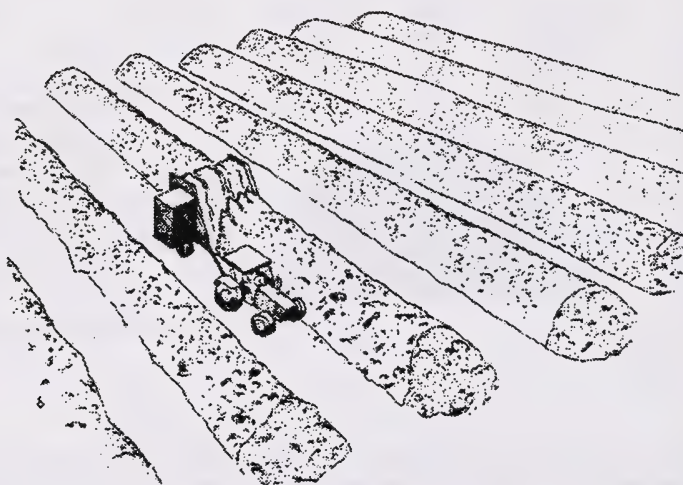
Source: On-Farm Composting Handbook, Page 6.

Forming Windrows

Windrows can be formed using a number of technologies and practices. Most commonly, windrows are formed using a "skid steer loader" to pile the material.

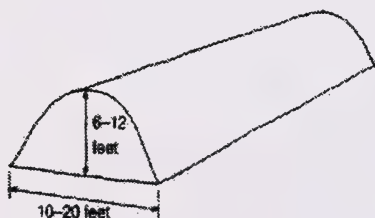
Equipment with a "long reach" such as bucket loaders can build high windrows. Turning machines produce low windrows. Large windrows can create anaerobic zones near the centre of the pile, which release odours when turned, whereas small piles may lose heat quickly and are then unable to evaporate moisture and to kill pathogens and weed seeds.

Aeration of windrows is either natural or passive air movement (convection or gaseous diffusion). Porosity in a windrow will determine the exchange of air. As a result, the size of a windrow that can be aerated effectively is determined by porosity. For example, a light fluffy windrow of leaves can be much larger than a wet dense windrow containing only grass clippings. Therefore, your feedstock will determine the size of the windrow.

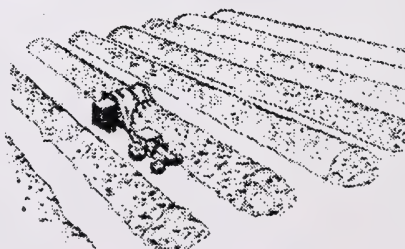


Windrow composting with an elevating face windrow turner.

Source: *On-Farm Composting Handbook*, pg. 25.



Bucket loader

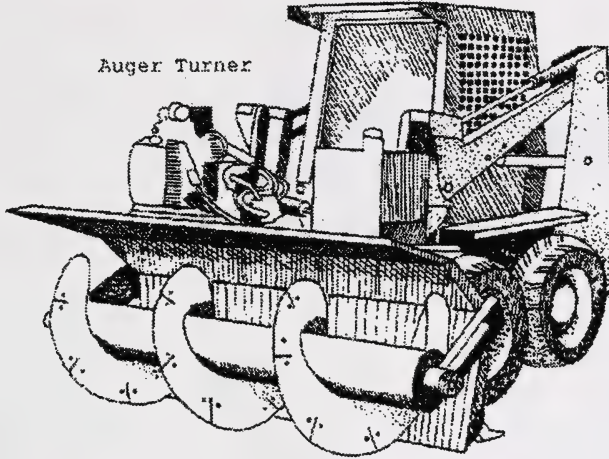


Windrow-turning machines

Typical windrow shapes and dimensions.

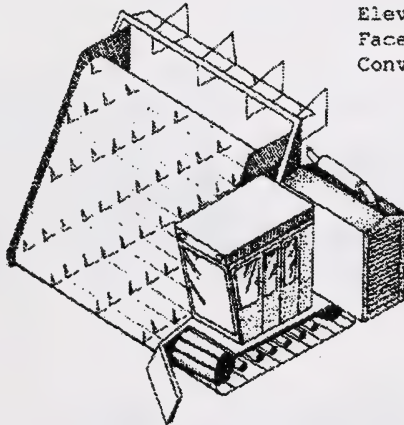
Source: *On-Farm Composting Handbook*, pg. 25.

Auger Turner

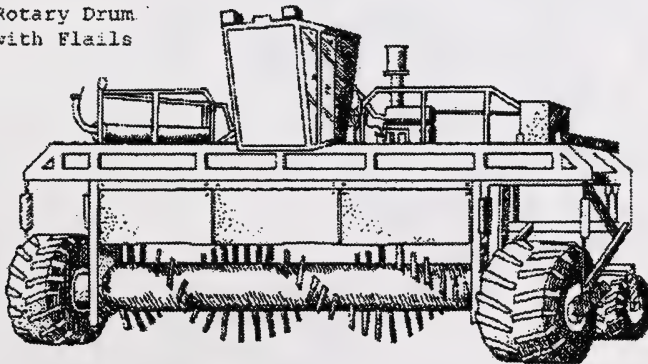


Source: *On-Farm Composting Handbook*, pg. 25.

Elevating
Face
Conveyor

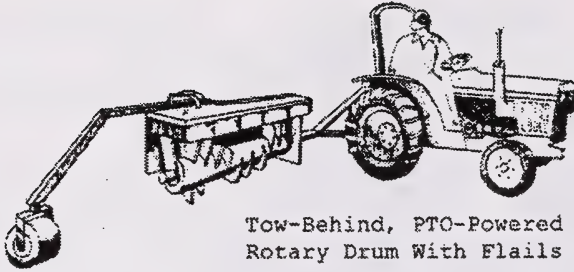


Rotary Drum
with Flails



Self-Powered and Self-Driven Windrow Turners. (above and previous page)

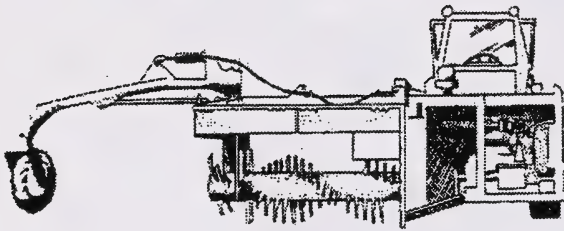
Source: *On-Farm Composting Handbook*, pg. 28.



Tow-Behind, PTO-Powered
Rotary Drum With Flails

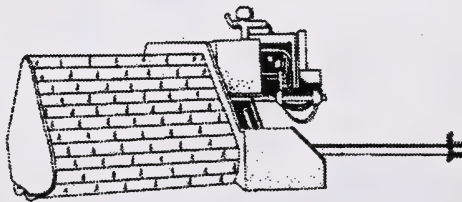
Tractor-Assisted Windrow Turner.

Source: *On-Farm Composting Handbook*, pg. 27.



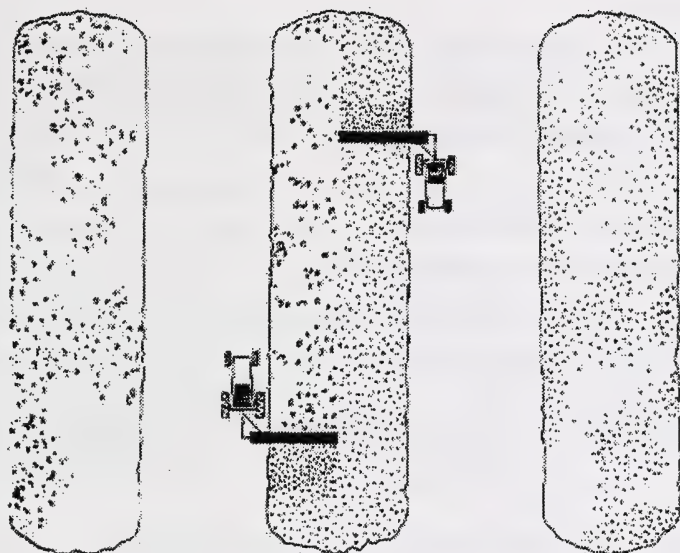
Push-Type,
Self-Powered
(diesel
engine)
Rotary Drum
with Flails

Tractor-Towed, Self-
Powered, Elevating-Face
Conveyor



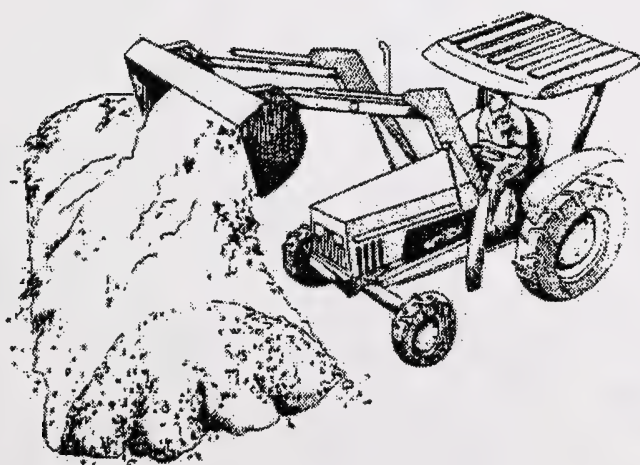
Tractor-Assisted Windrow Turners.

Source: *On-Farm Composting Handbook*, pg. 27.



Two Passes are Necessary for Most Tractor-Drawn Turners.

Source: On-Farm Composting Handbook, pg. 27.



Turning Windrows Using a Bucket Loader.

Source: On-Farm Composting Handbook, pg. 26.

Biological Activation

Biological Activation refers to the microbes within the compost. In new compost the microbes are present in small amounts, but in active compost they are present in much greater amounts. By adding a little active compost to new feedstock the time necessary to reach vigorous composting can be shortened.

Adding 10% to 15% of active compost to new feedstock should be sufficient to increase the rate of composting by a significant amount.

Composting leaf and yard waste is a **biological process**.

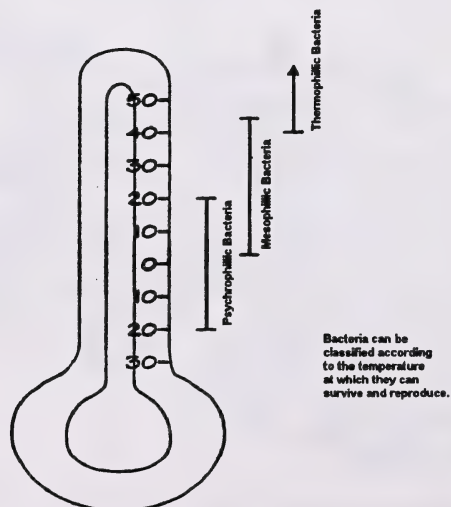
The composting process is designed to maintain a good healthy environment for the micro-organisms to break down organic matter. A compost pile is a teeming food web of organisms. Due to changing conditions in the pile, no one organism dominates.

Micro-organisms break down leaf and yard waste into simpler forms of proteins and carbohydrates. The nutrients then become available to a wider array of bacterial species that will carry them to a further stage of decomposition.

The three main groups of micro-organisms found in composting piles are:

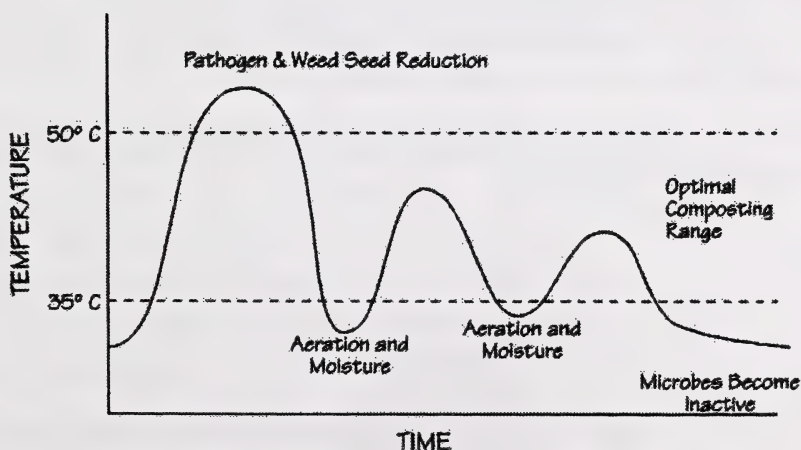
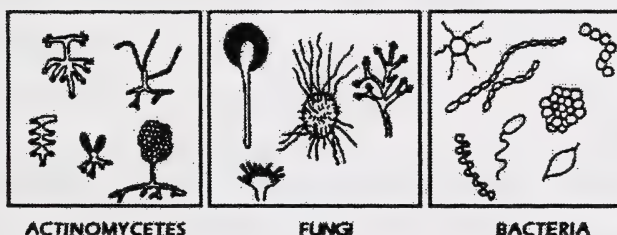
- Bacteria
- Fungi
- Actinomycetes

Bacteria are the most numerous organisms in the composting pile and are found in many forms. Bacteria can be classified according to the temperature at which they can survive and reproduce. The three main types of bacteria are psychrophilic, mesophylic, and thermophylic. These organisms are small and tend to be generally faster decomposers than other microbes.



Fungi are larger organisms and are also present in many forms. Fungi take over in the final stages of composting when the organic material has been changed to a more digestible form. They tend to thrive in a lower pH range and are tolerant of low-moisture conditions. Fungi are also able to decompose woody materials that are generally resistant to decay.

Actinomycetes are a higher form of bacteria, similar to fungi and mold, common in the early stages of the pile. Actinomycetes can be recognized by greyish, cobwebby growths that give a pleasing earthy smell to compost. The liberation of carbon, nitrogen and ammonia takes place in the presence of this type of bacteria. They are most often found in drier parts of the pile and can survive a wide range of temperatures and conditions. Actinomycetes will take over during the final stages of decomposition, often producing antibiotics, chemical substances that destroy other bacterial growth.



Turning and Mixing

Turning and mixing the compost is necessary to blend in any amendments, as well as to introduce oxygen into the compost.

The objectives of turning and mixing are as follows:

- Blend in added water uniformly
- Homogenize the compost
- Break up large clumps of material that may turn anaerobic
- Aid in the physical breakdown of materials
- Expose all material to high temperatures to kill pathogens
- Introduce oxygen to the compost
- Rebuild porosity of windrow
- Exchange material at the windrow's surface with material from the interior

Deciding when to turn the compost depends on a large number of factors, the most important being:

- Oxygen content
- Temperature
- Moisture content

The frequency of mixing and turning will be dependent mainly on temperature and moisture content.

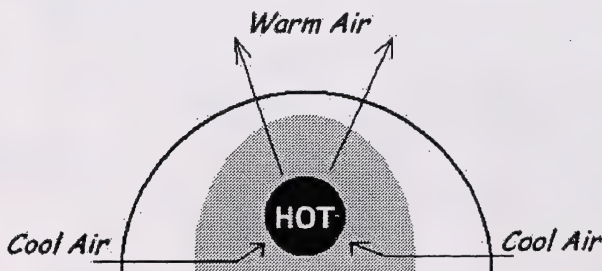
It is very important to maintain a schedule of turning.

During fly season, the windrows should be turned once a week despite temperatures. Weekly turnings break the fly reproductive cycle.

Oxygen Content

Oxygen content is a key factor in deciding when to turn compost. A high oxygen content must be maintained in order for the microbes to work under aerobic conditions. By monitoring the oxygen content and by noting when it drops below the desired O₂ readings (16-22%) it can be determined whether or not the compost needs to be turned.

Remember to calibrate (to make sure your probe is reading correctly) your probe weekly to ensure accuracy.



Monitoring Oxygen

To monitor oxygen:

1. Use a long oxygen probe
2. Insert probe into pile 40cm
3. Aspirate (pump) the bulb 6 times
4. Record the Reading



Temperature

Temperature also plays a part in determining when the compost needs to be turned. Heat is generated as a by-product of bacterial activity in the pile. The most favourable range for composting is from 40-50°C. At temperatures below 35°C, the microbes (the favoured ones) will become inactive. At temperatures above 55°C the microbes will begin to die off.

Controlling Temperature

Temperature must be controlled to ensure three things:

1. **Reduction of any pathogenic species as well as weed seeds, that may be present in the compost.** Pathogens are commonly occurring disease-causing organisms that may be found in the leaf and yard waste feedstock.

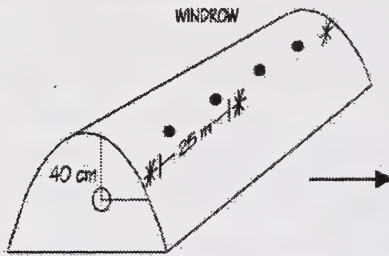
The process of reducing pathogens requires temperatures exceeding 55°C for a minimum of 15 days. This will ensure that pathogenic levels are kept at as low a level as possible. Once this has been achieved, temperatures may be allowed to fall back down to the optimal level (40-50°C).

2. **The temperature must be maintained at a level where the microbes are working at their optimum performance.** Temperature is the main limiting factor in aerobic composting. Because peak decomposing takes place over the mesophilic and the thermophilic ranges combined, the optimum temperature range for peak decomposition is 40-50°C. Therefore it is necessary to keep the temperature of the compost as close to this range as is possible. When temperatures exceed the desired maximums (after 15 days) the compost must be turned.
3. **Maintaining optimum temperatures will help reduce the time necessary for processing.** The temperatures are kept at a relatively constant level, the product will tend to be much more uniform. This reduces the number of steps needed to make the product more saleable.

When temperatures reach the upper limit (50°C) the compost should be turned to ensure an optimum environment for the microbes.

Monitoring Temperature

Temperature is monitored by the use of a long stem thermometer at depths and distances throughout the windrow sufficient to give a good cross section of the entire pile.



* = sampling positions on alternate sides of windrow

Ensure you take temperatures at the core of the pile.

By keeping temperatures at an elevated level, most weed seeds are generally inactivated. Controlling pathogens also controls the possibility of weed contamination.

Moisture

Moisture is also a key factor in determining when compost needs to be turned. The target moisture level for compost is about 50%. Therefore when moisture content falls below the desired level, water should be added to reach desired levels and the compost turned. This is easily accomplished by soaking down the windrow.

Aerated Pile to Accelerate Drying Process



50%

Optimum Moisture



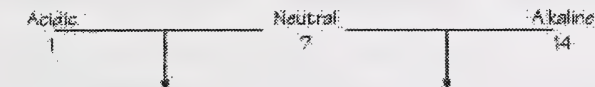
Add Moisture (water or leachate)

Controlling pH

During composting pH can help indicate:

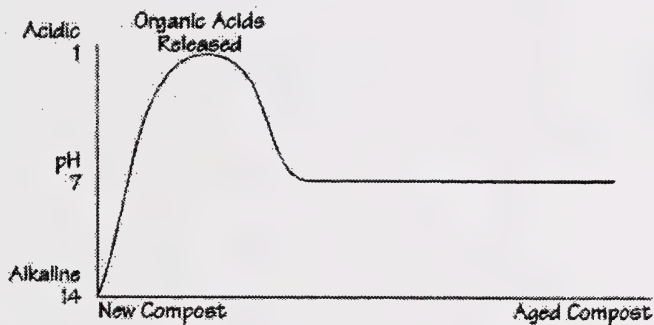
- The types of microbes present
- The level of microbial activity
- How corrosive the material is

pH



May signal that compost has gone from aerobic to anaerobic.
= odour - Nitrogen lost as ammonia
= contamination of material due to possible dissolving of metals.

The pH of the feedstock will vary with different types of material. However, pH should not be adjusted using alkaline or acidic additives. Instead decreasing the aeration should control pH. Decreasing the aeration will cause the pH to rise (become alkaline).



Normal pH cycle.

TESTING pH

Saturate the compost sample with distilled water, letting the compost settle and take the pH by conducting a litmus test.



Length of Active Composting Stage

The length of the active composting stage is dependent on:

- Nature of materials
- Frequency of turning

Active composting can take from three to nine weeks. If the desired rate of composting is fast, turn the windrow once or twice a day during the first week and every three to five days thereafter.

8. Composting Stabilization

Compost stabilization occurs after maximum composting rates have passed or, in other words, when the level of biological activity starts to decline. During compost stabilization there is still a demand for oxygen and temperatures may remain quite high. The moisture content should be maintained around 50%. This will help maintain the biological activity necessary to stabilize the compost.

Compost stabilization is complete when:

- Phytotoxic fatty acids have broken down
- The biological activity in the compost will not deplete the nitrogen in the host soil
- Further weight reductions in the compost will not concentrate chemicals found in the compost (i.e. homogeneity)

Nitrogen immobilization occurs when materials with a high C:N ratio are land applied. The microorganisms that use the carbon also assimilate the available nitrogen, making it unavailable to plants.

9. Compost Curing

The curing of compost occurs after most of the available material has been metabolized; after determinants such as temperature and oxygen levels have shown that microbial activity has finished. Curing allows for further decomposition of more complex organic structures, such as lignins, cellulose and large molecular organics. This process is achieved when the compost is left in piles for at least one month.

The compost curing stage allows the composted material to finally stabilize, resulting in a mature compost. During this stage microbes turn extra carbon into carbon dioxide and humus and extra nitrogen into nitrates.

What is needed at this stage to allow for a low level of microbial activity:

- Less oxygen
- Moisture levels of 40 to 45%
- Aeration levels of 16%
- pH levels of 6.0 to 8.0

How Do You Know When Your Compost is Finished?

Characteristics of mature compost include biostabilization (microbial activity has ceased) and humus formation. Guidelines for compost maturity are necessary as immature product has the potential to cause adverse affects on plants when applied in large amounts.

At present, no single test of compost maturity is reliable and sufficient by itself, therefore, the use of more than one test is recommended. The compost must conform to one of the following:

1. Two of the following three test requirements should be met:
 - Testing for the ratio of carbon and nitrogen, which must be C/N less than or equal to 25.
 - Oxygen uptake of less than 150mg oxygen per kilogram of organic matter (volatile solids) per hour.
 - The germination of cress (*Lepidium sativum*) seed and radish (*Raphanus stivus*) seed in compost shall be greater than a value corresponding to at least 90% of the germination rate of the control sample. Plant growth rate of the compost-soil mix shall not be less than 50% in comparison to plant growth of the control sample.

Bulk Density – Bulk density is expressed in weight per unit volume. Bulk density will tend to increase as the composted materials structure breaks down, however, moisture content of the material may lead to false conclusions (the more water retained in the compost the heavier it will appear). In order to measure bulk density: take a container of known volume, fill the container with compost, weigh the container with compost, record your results as kg/m³.

Soluble Salts – Soluble salts are measured using electrical conductivity, which is commonly expressed as millimhos/cm (mmhos/cm) or as millisiemens/cm (mS/cm) As the soluble salt content increases so does the electrical conductivity. A compost sample with a high conductivity may be phytotoxic to plants. Soluble salts are measured by: (remember this is conducted at off-site labs) take a sample of compost, saturate sample with distilled water, allow sample to settle, measure conductance of the solution.

Seed Germination – This evaluates a compost ability to grow plants. It involves placing a known number of seeds on a layer of compost, and counting the number of plants that germinate. A control plant is also grown for comparison.

OR

2. The compost must be cured for a minimum of 21 days and the compost will not reheat upon standing to greater than 20°C above ambient temperature.

OR

3. The compost must be cured for a minimum of 2 days and the reduction of organic matter must be greater than 60% by weight.

OR

4. If no other determination of maturity is made, then the compost must be cured for a six-month period. The state of the curing pile must be conducive to aerobic biological activity. The curing stage begins when the pathogen reduction process is complete and the compost no longer reheats to thermophilic temperatures.

Other factors may also help determine when compost has matured.

Odour can be a factor in determining if the compost process is complete. Compost that is near completion will have an earthy smell, as opposed to compost that is not near completion, which may have a variety of odours.

Colour may also be a factor in determining the readiness of compost for use. As most compost matures the colour will begin to take on an earthy appearance and take on a dark brown or even black colour. Moisture content will also influence the colour. Compost that is very moist will have a darker appearance, than similar compost that is very dry.

10. Compost End Use

Compost can be used for:

- Parks
- Household, lawns, and gardens
- Green Spaces
- Soil Reclamation
- Potting Mediums ...

Depending on the compost end use, steps may need to be taken in order to make the product saleable. The product may need to be:

- Screened
- Dried
- Bagged
- Blended

Compost Screening

Screening compost removes contaminants and creates a uniform product. This procedure is carried out prior to blending (with soil additives for a value-added product) and shipping. The demand for screened compost will depend on customer needs.

Biodegradable rejects can be stored and added to active compost, whereas, all non-biodegradable material should be disposed in an appropriate manner.

Drying

At this stage most of the biological activity will have declined. Therefore, screening requires that moisture content of the material be between 30-45%. Moisture content that exceeds this level may hamper the screening process by forming clumps and/or plugging the screen.

Blending

At this stage products such as vermiculite and perlite can be added to the compost to increase its value to meet the needs of specific markets.

Storing and Bagging

Compost storing and packaging will depend on the needs of the customer. Generally, storing and bagging requires:

- Moisture levels of 45%. Less than 45% moisture will create dust, and greater than 45% moisture will make compost heavy for shipping.
- A neutral pH of 6.0 to 8.0. pH levels above or below neutral can be corrosive.

APPENDIX A

Trouble Shooting

Symptom	Problem	Solution
Smells like rotten eggs	Pile has gone anaerobic. <ul style="list-style-type: none"> - pile is compacted - pile is too wet 	<ul style="list-style-type: none"> - Aerate the pile - Add bulking agents - Mix in dry materials
Smells like ammonia	Nitrogen levels are too high	Adjust C:N ratio by adding materials high in carbon such as leaves, wood chips, sawdust, etc.
Process is too slow	The weather is too cold and the pile is not insulated. The particles in the compost are too large.	Insulate your pile by reforming it and making it larger. <ul style="list-style-type: none"> - Shred the materials in your pile
Pile is damp and does not have a bad odour but will not heat up.	Lack of nitrogen.	Mix in high nitrogen materials such as grass clippings.
The centre is dry	No enough moisture.	Add water while turning the compost pile to reach moisture levels of 40 to 50%.
Insects	Exposed raw materials.	Move materials from receiving pad as quickly as possible, or turn and mix on the receiving pad. <ul style="list-style-type: none"> • Turnings should be daily to beat the fly cycle.
Vectors / rodents	Unattended windrows	Maintain active composting. If severe, use fabric tarps to cover the material.
Low pH	Anaerobic conditions.	Aerate the material.

APPENDIX B

Additional Resources and Contacts

- Alberta Environment: *"Code of Practice for Compost Facilities"* - order from Queen's Printer Bookstore
11510 Kingsway Avenue, Edmonton, AB T5G 2Y5
Phone: (780) 427-4952 or Fax (780) 452-0668
- Alberta Environment: *"A Full Cost Analysis Guide for Municipal Waste Managers"*
- The Composting Council of Alberta: *"Composting Technologies and Practices"*
- CCME Canadian Council of Ministers *"Guidelines for Compost Quality"* - order from CCME documents c/o Manitoba Statutory Publications of the Environment
200 Vaughn Street, Winnipeg, MB
Phone (204) 945-4664 or Fax (204) 945-7172
- Composting Technology Centre, Olds College: *"Compost in a Crate"*
Phone (403) 556-4745 or Fax (403) 556-4718

Composting Web Sites

The Compost Heap

www.geocities.com/ramforest/8262/

The Compost Resource Page

www.oldgrowth.org/compost/

Compost Simplified - Organic Gardening Basics

www.10wacity.com/city/compost.htm

Nicholas Parks Homepage - Composting Plan

www.ritaldes.demon.co.uk/

Resource Efficient Yard Care and Composting

www.rain.org/~swmd/backyard.html

Making Compost Happen

www.wa.gov/ecology/swfa/

The Composting Council

www.composter.com/composting/compccouncil/

The Composting Council of Canada

www.compost.org/

Olds College

www.oldscollege.ab.ca

APPENDIX C

Definitions

Aeration	The process by which the oxygen-deficient air in compost is replaced by air from the atmosphere. Aeration can be enhanced by turning the compost, by passive aeration or by forced aeration using blowers.
Bulking Agents	An ingredient in a mixture of composting raw materials included to improve the structure and porosity of the mix. Bulking agents are usually rigid and dry and often have large particles (e.g. straw or wood chips). The terms "bulking agents" and "amendment" are commonly used interchangeably.
Carbon-to-Nitrogen Ratio	The ratio of the weight of organic carbon (C) to that of total nitrogen (N) in an organic material.
CCME	Canadian Council of Ministers of the Environment
Co-composting	Composting two or more distinctly different materials together, generally as a strategy for achieving a better balance of carbon and nitrogen, or favourable moisture content. Usually refers to the composting of solid wastes, which are relatively dry and carbon-rich, with wet sewage sludge, which is rich in nitrogen.
Compost	A stable humus-like material that results from the biological decomposition and stabilization of organic materials under aerobic and thermophilic conditions. Compost is potentially beneficial to plant growth, and is sanitized to a degree that protects human and plant health.
Composting	Biological degradation of organic matter under aerobic conditions to a relatively stable humus-like material called compost.
Contaminant	A Contaminant is an element, compound, substance, organism or form of energy, which through its presence or concentration causes an adverse effect on the nature environment or impairs human use of the environment.
Contamination	Any introduction into the environment (water, air, soil) of micro-organisms, chemicals, wastes, or wastewater in a concentration that makes the environment unfit for its intended use.
Curing	Final stage of composting in which stabilization of the compost continues but the rate of decomposition has slowed to a point where turning or forced aeration is no longer necessary. Curing generally occurs at lower, mesophilic temperatures. Used synonymously with maturing.
Degradability	Term describing the ease and extent that a substance is decomposed by the composting process. Materials that break down quickly and/or completely during the time frame of composting are highly degradable. Materials that resist biological decomposition are poorly or even non-degradable.
Foreign Matter	Any matter resulting from human intervention and made up of organic or inorganic components such as metal, glass, synthetic polymers (e.g. plastic and rubber) that may be present in the compost. Foreign matter does not include mineral soils, woody material, and rocks.

Feedstock	Materials that contain organic materials that decompose biologically.
Heavy Metals	A group of metallic elements that include lead, cadmium, zinc, copper, mercury, and nickel. They occur in small quantities in all soils and can be found in considerable concentrations in sewage sludge and several other waste materials. High concentrations in the soil can lead to toxic effects in plants and animals ingesting the plants and soil particles. Federal and provincial regulations restrict the land applications of materials that contain high concentrations of heavy metals.
Humus	The dark or black carbon-rich, relatively stable residue resulting from the decomposition of organic matter.
Leachate	The liquid that results when water comes in contact with a solid and extracts material, either dissolved or suspended from the solid.
Lignin	A substance that, together with cellulose, forms the woody cell walls of plants and the cementing material between them. Lignin is resistant to decomposition.
Mesophilic	Operationally, the mid-temperature range most conducive to the maintenance of optimum digestion by mesophilic bacteria, generally accepted as between 10 and 40 (50 and 105°F)
Micro-organisms	A living organism so small that it requires magnification before it can be seen.
Moisture Content	The fraction or percentage of a moist substance that is water.
MSW	Municipal Solid Waste
N.P.K.	A common combination of fertilizer nutrients, the chemical symbols for Nitrogen, Phosphorus, and Potassium.
Pathogen	Any organism capable of producing disease or infection. Often found in waste material, most pathogens are killed by the high temperature of the composting process.
pH	A measure of the concentration of hydrogen ions in a solution. pH is expressed as a negative exponent. Thus something that has a pH of 8 has ten times fewer hydrogen ions than something with a pH of 7 does. The lower the pH, the more hydrogen ions present, and the more acidic the material is. The higher the pH, the fewer hydrogen ions present, and the more basic it is. A pH of 7 is considered neutral.
Phytotoxic	An adjective describing a substance that has a toxic effect on plants. Immature or anaerobic compost may contain acids or alcohol that can harm seedlings or sensitive plants.
Pilot Program	A scaled-down version of a planned program designed to test the operation on a sample of the material or of the population involved, as a means of verifying numerical data or other assumptions used in the system design before committing greater resources to the full-scale operation.
Source Separation	Separation of the waste materials into two or more distinct components prior to collection to limit the possible contamination of one material stream by the other.

Stability of Compost	The reduced rate of change or decomposition of compost as it approaches maturity. Usually stability refers to the lack of change or resistance to change. A stable compost continues to decompose at a very slow rate and has a low oxygen demand.
Thermophilic	Heat-loving micro-organisms that thrive in and generate temperatures above 40°C.
Tipping Fees	Fees charged at the point of reception for treating handling and/or disposing of waste materials.
Turning	A composting operation which mixes and agitates material in a windrow pile or vessel. Its main aeration effect is to increase the porosity of the windrow to enhance passive aeration. It can be accomplished with bucket loaders or specially designed turning machines.
Waste Diversion Potential	The capacity to divert waste material or materials from ultimate disposal by landfilling or incineration, by employing the hierarchy of Rs - Reduce, Reuse, Recycle. Incineration is a waste-to-energy plant is usually classed as Recovery, the 4 th R, and is still a means of waste diversion.
Wet/Dry Collection	A 2-stream system of source separation whereby the recyclable materials are placed in one container, forming the "dry" waste stream, and other materials are put in a second container. The second, "wet" stream, is often either landfilled or further treated to remove the compostable material from the ultimate remnant which is landfilled. Not that in a 3-stream collection system the recyclable and compostable materials are both separated at source from what is considered to be garbage to be landfilled.
Windrow	A long, relatively narrow and low pile. Windrows have a large exposed surface area that encourages passive aeration and drying.
Yard Waste	Leaves, grass clippings, yard trimmings, and other organic debris.

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